Towards a robust new radio compatible with XR
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Session 1: Enabling future wireless communication systems

Paper S1.2: Towards a robust new radio compatible with XR
Outline

- Background of eXtended Reality
- Traffic models for XR
  - Single-stream model
  - Data fitting approaches
  - Data fitting results
  - Multi-stream model
- Proposed priority-based adaptive preemptive scheduler
  - Challenges posed by XR to Rel-16 NR
  - Elaboration of our proposed scheduler
  - Simulation results
- Further study and improvements
Background of eXtended Reality

- **Business prospects:** The market margin for XR service is expected to largely exceed US$180 million by the end of 2021 considering meta universe hype.
- **Challenge:** New radio air interface improvement from the 4 dimensions (Capacity, power, coverage, mobility).
- **Industrial vision:** Rel-17 RAN1 SI, Rel-18 WI, SA4 (S4aV200575), SA2 (S2-2102370)
Traffic models for XR

- Parameters for truncated Gaussian distribution
  - Mean packet size
  - Maximum packet size
  - Minimum packet size
  - Packet size deviation
  (Note: STD/Max/Min are determined from the ratio w.r.t Mean)

- P-trace provided by SA
  - The j-th packet sizes calculation: \( N_j = \sum_{i=1}^{x} n_{j,i} \)
  - The packet sizes sample: \( \{N_1, N_2, \ldots\} \)

<table>
<thead>
<tr>
<th>Size</th>
<th>...</th>
<th>Rendering time</th>
<th>...</th>
<th>importance</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n_{1,1} )</td>
<td>...</td>
<td>0</td>
<td>...</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>...</td>
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<td>...</td>
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<tr>
<td>( n_{1,x} )</td>
<td></td>
<td>0</td>
<td>...</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>( n_{2,1} )</td>
<td>...</td>
<td>16667</td>
<td>...</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>...</td>
<td>...</td>
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Data Resource: http://dash.akamaized.net/WAVE/3GPP/XRTraffic/Traces/Candidate/VR2/
Data fitting approaches

- Alt 1: Directly use inherent feature of data samples
  - Mean packet size: $N_{\text{mean}} = \frac{\sum_{i=1}^{M} N_i}{M}$
  - Packet size standard deviation: $N_{\text{STD}} = \sqrt{\frac{1}{M} \sum_{i=1}^{M} (N_i - N_{\text{mean}})^2}$
  - Relationship between STD and mean: $N_{\text{STD}} / N_{\text{mean}}$

- Alt 2: Extract the inherent noise-free statistical characteristics
  - Pre-filtering
  - Preliminary estimation

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Pre-filtering

Find maximum and minimum packet size in sample

Determine an envelop interval $[X,Y]$, where $X < \min < \max < Y$

Divide the envelop interval $[X,Y]$ to $R$ subintervals, each subinterval has $L$ intergers

Obtain the $i$-th noise-free packet size sample according to $x_i = X + (i-1)L + L/2, i = 1,2,..., R$

Estimation

Calculate the relationship between standard deviation and mean

Estimate mean and standard deviation for sample set $\{x_i\}$
Data fitting results

- The sample noise causes some deviation in the mean and variance of the fitted data with Alt 1.
- The traffic derived with Alt2 is in much closer vicinity to actual sample distribution.
- Observations:
  - Packet size deviation = 3% * Mean packet size
  - Maximum packet size = 109% * Mean packet size (3 sigma principle)
  - Minimum packet size = 91% * Mean packet size (3 sigma principle)

![Alt1 fitting results](image1)

![Alt2 fitting results](image2)
Multi-stream model

- An XR service typically consists of multiple flows with different Quality of Service (QoS) requirements ranging differently in terms of data rate, periodicity, reliability, latency, etc.
- Typical multi-stream model
  - Audio stream and video-stream
  - Typical multi-stream model for XR video
    - I-stream and P-stream (Models for I/P-stream have been captured in TR, where packet size ratio = 2)
    - FoV-stream and non-FoV stream

Agreed traffic model for I/P-stream traffic model traffic model

Proposed traffic model for FoV and non-FoV traffic model
Priority-based adaptive preemptive scheduler

- Challenge for XR traffic transmission
  - A huge transport block in a jittering arrival manner.
  - The stringent QoS requirement of reliability and latency.
- XR transmission implementation -- Coexistence with existing uRLLC and/or eMBB.
  - How XR service coexists with current existing service like uRLLC or eMBB, without excessive performance loss.
  - Preemption mechanism can be one of the solutions for XR service coexistence.

Framework on proposed scheduler

- Proposed priority-based adaptive preemptive scheduler is capable of ensuring high priority UEs transmission on time.
- Proposed priority-based adaptive preemptive scheduler sacrifices low priority UEs to multiplex high priority UEs without too much performance loss on low priority UEs.
Priority-based adaptive preemptive scheduler

<table>
<thead>
<tr>
<th>Parameters settings</th>
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<tbody>
<tr>
<td>UE importance signal flag: $I$</td>
</tr>
<tr>
<td>Reference HP UE number: $k$</td>
</tr>
<tr>
<td>Weighted coefficient: $f$</td>
</tr>
</tbody>
</table>

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<tr>
<th>Ordering module</th>
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<tbody>
<tr>
<td>Calculate average throughput $T'$ of all UEs and weigh the $T'$ based on UE importance signal flag $I$</td>
</tr>
<tr>
<td>Find $k$ best UEs according to weighed throughput $T'$; obtain their CQI report and average their CQI reports to re-order the subband</td>
</tr>
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<thead>
<tr>
<th>Scheduling module</th>
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<tbody>
<tr>
<td>Assign $k$ best UEs firstly based on the re-ordered subbands</td>
</tr>
<tr>
<td>Schedule the rest UEs according to the metric, where the metric of HP UE are weighed by $f$</td>
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- **Throughput calculation:**
  - Throughput calculation:
    $$ T' = T \cdot I, \quad T = \left\{ T_i \right\}_{i=1}^{\text{UENum}} $$
    $$ T_i = \frac{1}{N_{\text{RB}}} \sum_{j=1}^{N_{\text{RB}}} r_j(i) \cdot N_{\text{RB}} \cdot v, \quad i = 1, \ldots, \text{UENum} $$
  - Identify the importance of UEs to assist scheduling and resource allocation.
  - Use HP UE's CQI report for reorder subband resource for the whole system.

- **Weighed metric for the rest UEs (remaining HP UE and LP UE):**
  $$ M_j = \frac{T_{i_{\text{ave}}}}{T_{i_{\text{ave}}}} \cdot F(I(i)) $$
  $$ F(x) = \begin{cases} 1, & x = 0 \\ f, & x = 1 \end{cases} $$
  - Identify the importance of UEs to assist scheduling and resource allocation.
  - Configure the parameter $f$ to affect the opportunities for HP UE preempting.
Observations:

- Priority-based adaptive preemptive scheduler provides around 12.5 percent capacity gain for SU-MIMO systems.
- The proposed scheduler can also be used in multi-stream model (e.g. FoV and non-FoV) and more performance gains are expected.

### Simulation Results

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
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<tbody>
<tr>
<td>Scenario</td>
<td>Indoor Hotspot</td>
</tr>
<tr>
<td>Traffic Model</td>
<td>(HP) Traffic 1: Bit rate = 1.8Mbps, packet delay budget = 5ms.</td>
</tr>
<tr>
<td></td>
<td>(LP) Traffic 2: Bit rate = 30Mbps, packet delay budget = 15ms.</td>
</tr>
<tr>
<td></td>
<td>(according to conclusions of data fitting method Alt2)</td>
</tr>
<tr>
<td>Scheduler</td>
<td>Option 1: Proportion fair scheduler</td>
</tr>
<tr>
<td></td>
<td>Option 2: Proposed scheduler</td>
</tr>
<tr>
<td>TDD pattern</td>
<td>DDDSU</td>
</tr>
<tr>
<td>Target BLER</td>
<td>10% for first transmission</td>
</tr>
</tbody>
</table>

More simulation parameters are listed in our paper S1.2: Towards a robust new radio compatible with XR.
Further study and enhancements

• Enhanced QoS for different services
  • QoS info. with finer granularity for better representing user experience.
  • Further study how to use this kind of information to aid RAN transmission
• Preemption in multi-user MIMO scheduler
  • How to balance the relationship between UE-pairing and preemption in scheduler.
• Priority-based adaptive preemption for Multi-stream model
  • Intra-stream preemption should also be considered in scheduler.
• CBG mechanism for re-transmission
  • CBG re-transmission is capable of increasing the radio resource utilization efficiency in system.
Thank you!